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TECHNOLOGY UTILIZATION

# TESTING METHODS AND TECHNIQUES



## A COMPILATION

NATIONAL AERONAUTICS AND SPACE ADMINISTRATION

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## A COMPILATION

TECHNOLOGY UTILIZATION OFFICE 1970
NATIONAL AERONAUTICS AND SPACE ADMINISTRATION
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# Foreword

The National Aeronautics and Space Administration and the Atomic Energy Commission have established a Technology Utilization Program for the dissemination of information on technological developments which have potential utility outside the aerospace community. By encouraging multiple application of the results of their research and development, NASA and AEC earn for the public an increased return on the investment in aerospace research and development programs.

The technology presented represents testing methods and techniques that have evolved from a number of space programs. Industry should find these items economical, efficient, and time saving in the conduct of its quality assurance and other test activities.

This compilation covers a selected group of nondestructive tests for materials, welds, valves and tubing, wire insulation, bearings, and instrumentation fittings. Other tests include means for determining gas contamination, detecting hydrogen fires, detecting leakage in pressure transducers, and conducting shock tests of large items. Several computer programs that may be applicable to industrial testing are also presented. The information is intended primarily for skilled technicians and engineers with practical experience in quality control, inspection, and industrial testing.

Additional technical information on individual methods and techniques can be requested by circling the appropriate number on the Reader's Service Card included in this compilation.

Unless otherwise stated, NASA and AEC contemplate no patent action on the technology described.

We appreciate comment by readers and welcome hearing about the relevance and utility of the information in this compilation.

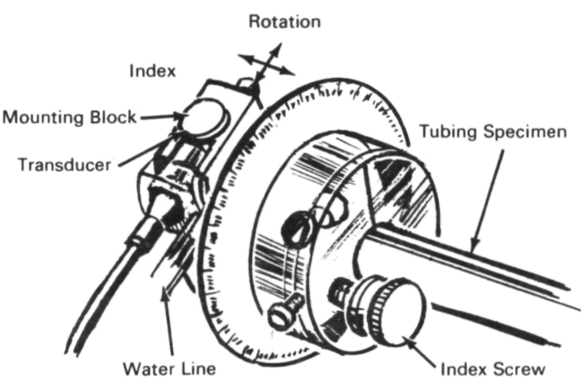
Ronald J. Philips, *Director*
*Technology Utilization Office*
*National Aeronautics and Space Administration*

# Contents

# Section 1. Nondestructive Testing

## TESTING OF WELDS ON THIN-WALLED TUBING

A special ultrasonic search device has been developed for the inspection of the quality of melt-through welds on fusion-welded tubing couplers for hydraulic lines. It is used in conjunction with high-resolution ultrasonic equipment for the inspection of welded tubing with diameters of 0.25 to 1.0 in. and wall thicknesses of 0.028 to 0.095 in.




The device consists of (1) a 7/16-in.-diameter × 1/2-in.-long ultrasonic (25 MHz) transducer contained in a mounting block having a water-line connector; (2) a nonrotatable, ("clamshell") plastic housing with index screw and pointer; and (3) a rotatable clamshell housing with circular protractor scale.

To perform an inspection, the transducer (in the rotatable housing) is rotated circumferentially about the weld, while ultrasonic response is observed on an oscilloscope at 10-degree intervals. A visible pattern of the weld quality recorded on the oscilloscope indicates any of the following melt-through weld conditions: no penetration, partial penetration, full penetration, and excessively rough outer surface. After 36 circumferential readings are completed, the index screw is rotated a half turn to index the transducer assembly 0.020 in. axially along the weld. The circumferential scanning procedure is then continued at this axial position and successive 0.020-in. increments until the entire weld is covered. The quality of the weld is evaluated from the point-by-point oscillograms.

The device can also be used to detect faulty braze bonds in thin-walled, small-diameter joints, and in the wall thickness of thin-walled metal tubing.

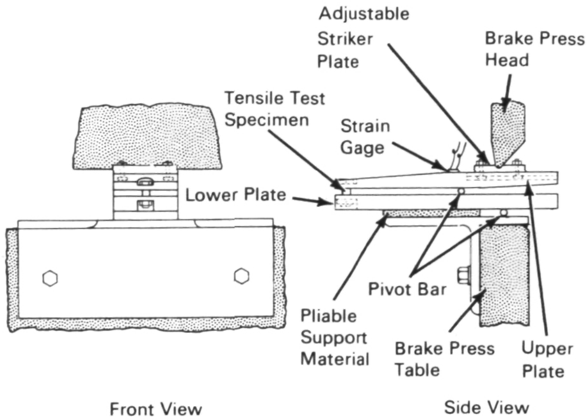
Source: D. J. Hagemaier and G. J. Posakony
North American Rockwell Corp.
under contract to
Marshall Space Flight Center
(MFS-18144)

*Circle 1 on Reader's Service Card.*

## TENSILE TESTING WITH A MODIFIED BRAKE PRESS

A standard brake press has been modified into a machine for testing tension. The fixture for the machine consists of a pivot bar between a pair of plates that are arranged to oscillate over the pivot bar in a seesaw manner. Strain gages are mounted on one or both sides of the plates, as required, to sense the slightest flexing. A striker plate protects the upper plate from damage and acts as an adjustment plate. The fixture is supported on a standard sheet-metal or similar press by a T-bar support bracket together with a pliable support material and another pivot bar (see figure).

For a tensile test, the specimen is placed at the exposed end of the seesaw plates. The specimen can be retained by a canister or similar container, which surrounds the specimen and the end of the fixture. The striker plate and press stroke are adjusted to produce the required average test




rate, and the leads from the strain gage are connected to a readout device, such as an oscilloscope. The flexure of the plate displayed on the readout device indicates the actual resistance to failure of the specimen at that test rate.

Although the fixture described above is for tensile testing, one for shear testing can be built based on the same principle.

Source: Billy Dean Hagen of
Chrysler Corp.
under contract to
Marshall Space Flight Center
(MFS-01876)

*No further documentation is available.*

## TESTING WELDED OR BRAZED JOINTS DURING STRETCH FORMING

A more reliable and simpler testing procedure has been developed for determining the joint integrity of welded, brazed, riveted, or otherwise joined parts, such as circular shaped aircraft panels, pressure tanks, and various closures. In this test, a stretch-forming process is used to proof joined parts by applying pure tensile stress beyond the yield point of the material. Formerly, welded joints were tested by more costly procedures such as radiographic, dye penetrant, or ultrasonic.

To perform a test, the joined material is properly mounted and a stretch-forming press stresses it above its elastic limit, while conforming to the die shape. This action causes an expansion of about 1 percent, and there is little springback to the metal once it is stretched. A test can be monitored by either strain gages, tensiometers, or optical comparators.

Source: K. E. Wood of
North American Rockwell Corp.
under contract to
Marshall Space Flight Center
(MFS-14209)

*Circle 2 on Reader's Service Card.*

## TESTING FOR TRACE HYDROCARBON CONTAMINATION OF GASES

Several techniques have been developed for determining the hydrocarbon contamination in the quality control of gas production, for maintaining clean-room environments, and for industrial hygiene activities. These techniques, which can detect low concentrations of hydrocarbons, are: (1) gas-scrubber-infrared spectrophotometry, (2) flame ionization, (3) gas chromatography, and (4) gas-cell-infrared spectrophotometry.

In the gas-scrubber-infrared spectrophotometry technique a fully halogenated solvent is used to remove the hydrocarbons from the sampled gas. This technique is effective for detecting most hydrocarbons with high boiling points, but is extremely poor for the collection of hydrocarbons having boiling points below that of the collection media. The use of this technique is limited to the analysis of condensable hydrocarbons or the oil content of gases.

A hydrogen-oxygen flame is used to ionize the carbon atoms in the flame-ionization technique; the ions are then collected on a positive grid. The current produced is proportional to the numbers of carbon atoms present in the gas being tested. This technique is sensitive to hydrocarbons in the

solid, liquid, and gaseous state. It is an acceptable means for directly measuring the total concentration of hydrocarbons in a gas.

Gas chromatographs are highly selective because they separate different hydrocarbons into fractions; however, this is desirable for the analysis of specific hydrocarbons. The specific hydrocarbons are determined by the type of column used for separation and the conditions under which the instrument operates.

Another technique for determining the hydrocarbon contamination of a gas is one in which a gas cell together with infrared analysis is used. This technique is highly effective for vapors, but cannot be used if liquid hydrocarbons are present. Because the condensation of hydrocarbon droplets in the instrument causes contamination and damage to the gas cell, its reliability is limited.

Source: Jack P. Morris of
The Boeing Co.
under contract to
Marshall Space Flight Center
(MFS-01416)

*Circle 3 on Reader's Service Card.*

## EDDY-CURRENT INSPECTION OF TURBINE BLADES

An improved, simple test method based on the use of eddy currents has been developed for the material verification of turbine blades. This method can substantially improve the accuracy, increase the speed, and reduce the cost of such inspections.

A permanent cast mold of a silicone compound is made for each blade to be inspected. A hole is provided to attach an adjustable, eddy-current standard probe (0.25 in. in diameter). This probe can be used in the molds for all blades (when adjusted to the proper blade-to-probe distance), for the calibration of blade standards, and for blade inspection. Each blade is placed in the mold and the eddy current microamperage reading observed. The permanent mold holds each blade in the same position relative to the probe, thus standardizing the inspection and eliminating the many variables.

Source: W. L. Glynn of
North American Rockwell Corp.
under contract to
Marshall Space Flight Center
(MFS-14587)

*Circle 4 on Reader's Service Card.*

## DETECTING HYDROGEN FIRES WITH COPPER SCREEN WIRE

Because of the need to test hardware involving hydrogen, an economical method for detecting hydrogen fires was devised.

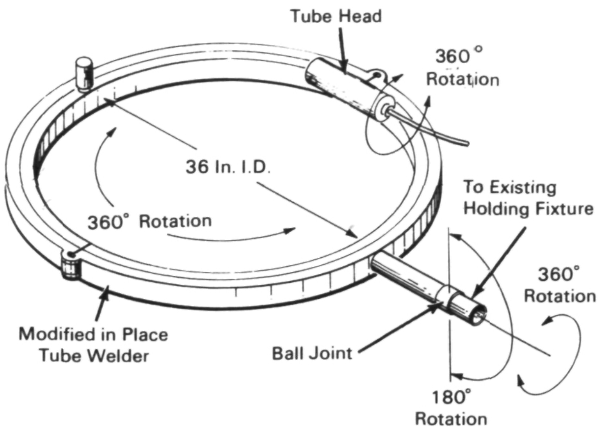
The addition of copper oxide to a normally colorless hydrogen flame gives it a characteristic color. Thus, old oxidized copper screen wire can be wrapped around an area suspected of hydrogen leakage, and if a fire occurs, the chemical reaction of hydrogen with copper oxide will color the flame green. The wire also changes color because of the heat from the hydrogen flame. New copper screen wire as well as oxidized wire may also be used, provided it is coated with a salt solution. In this case, the salt solution produces a red flame as the hydrogen fire burns through the screen.

Source: R. E. Burcham of
North American Rockwell Corp.
under contract to
Marshall Space Flight Center
(MFS-13100)

*Circle 5 on Reader's Service Card.*

## CONCEPTUAL IN-MOTION X-RAY MACHINE

A concept has been proposed for a lightweight, inexpensive in-motion X-ray machine for inspecting the weld of a tube or pipe (up to 15 feet in diameter) (see figure). It would have a split-ring drive system to allow the inspection of circumferential welds regardless of the length of the tube. This concept could reduce the time required for the radiographic inspection of irregularly shaped tubes by as much as 30 percent.




Because this proposed machine would weigh only about 50 lb, it could be adapted to the majority of handling devices presently used. The significant feature of this concept is the circular track that positions the tube head in order that it can be rotated around the piping or ducting. For normal tubing, the exposure is from the outside diameter; on larger piping and tanks, the exposure is from the inside diameter.

Source: W. W. Trujillo of
North American Rockwell Corp.
under contract to
Marshall Space Flight Center
(MFS-12672)

*Circle 6 on Reader's Service Card.*

## TESTING TUBING AT CRYOGENIC TEMPERATURES

A method has been designed for determining the pressure needed to rupture tubing at cryogenic temperatures of liquid hydrogen. This procedure may be useful in industry as a pressure-to-rupture test under cryogenic conditions.

A schematic of an apparatus for determining this critical pressure is shown in the figure. Hydrogen gas at 3000 psi is raised to the required pressure by a low-capacity gas-booster compressor and liquified by passing it through a tubing coil immersed in liquid hydrogen. The liquid hydrogen is then fed to the test piece (also in liquid hydrogen) through an orifice. At that time, the temperature and pressure in the test piece are recorded up to the instant of rupture with a thermocouple and a pressure transducer.

Source: H. Detering of
North American Rockwell Corp.
under contract to
Marshall Space Flight Center
(MFS-18180)

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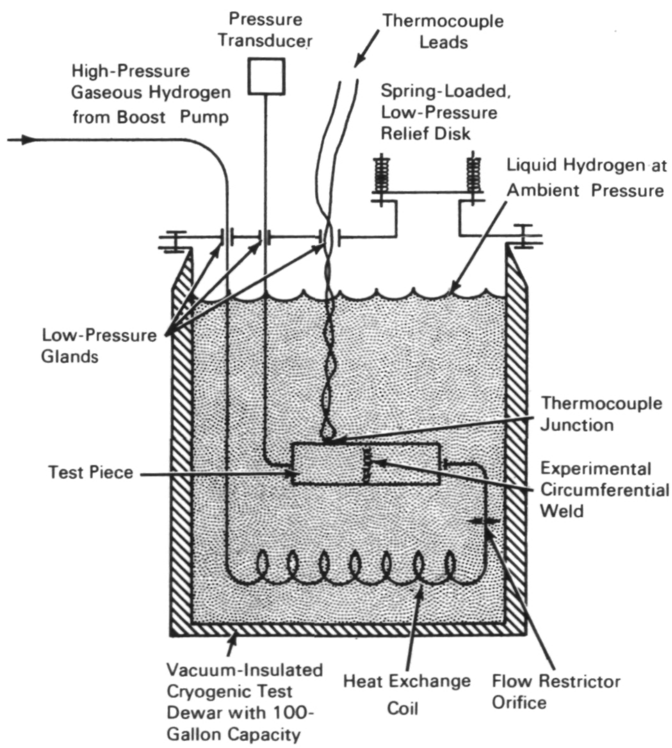
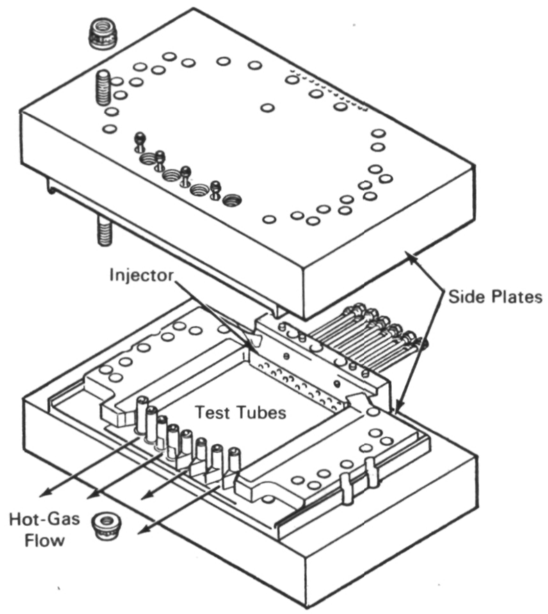


## COMPARATIVE EVALUATION OF MATERIALS UNDER HIGH-HEAT-FLUX CONDITIONS

An experimental procedure has been developed for testing materials in a high-heat-flux environment. It should be particularly applicable in the selection and evaluation of materials for high-temperature turbines, molten-metal pumps and piping, and equipment used in the high-temperature processing of metals and chemicals. A significant advantage of this technique is that a number of material variations and/or geometrical disarrangements can be comparatively evaluated under identical test conditions.




Internally cooled tubular specimens are inserted across the outlet of an oxygen/hydrogen combustor that can develop heat flux $\geq 80$ Btu/in.$^2$/sec in the specimens (see figure). The mixture ratio (oxygen/hydrogen) is variable over a narrow range, and the rate of flow is varied to produce combustion pressures from a few hundred to 2000 psi. A number of specimens may be inserted at one time so that comparisons between materials can be readily observed. Coolant is supplied and withdrawn through manifolds in the side plates. Control of the coolant mass flow rate and flow velocity through the tubular samples makes possible the control of heat rejection to the coolant.

Source: J. R. Lauffer of
North American Rockwell Corp.
under contract to
Marshall Space Flight Center
(MFS-18186)

*Circle 8 on Reader's Service Card.*

## TESTING INSULATION OF ELECTRIC WIRE

An apparatus has been developed to test spools of insulated electric wire for defects in the insulation material that may cause electric discharge. It senses defects in the insulation as wire is fed through an electric conducting media.

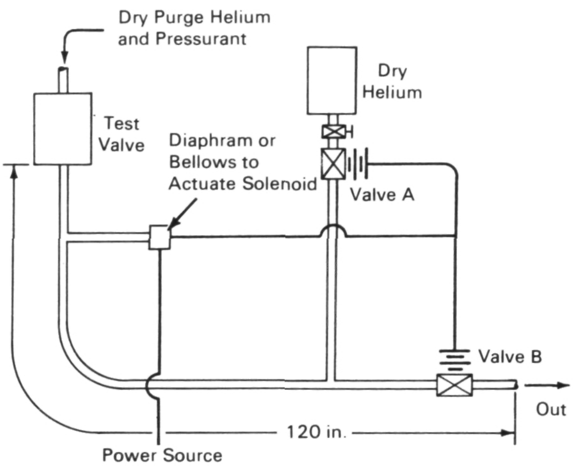
The apparatus is based on the principle that with an electrically charged conductive media surrounding the insulated wire, the wire conductor will complete the circuit to a revolving pickup point at a fixed end. The insulated electric wire is fed through an electrically isolated metal tube about three-fourths filled with small-diameter (1/16 in.) chrome-plated ball bearings. The starting end of the wire on a take-up spool is used as the conductor of the wire being tested and it is securely locked to the electrically isolated drive arbor of the take-up spool. An ac power source is connected to the base plate and the tube holding the ball bearings. A signal light and braking mechanism are activated the instant that a ball is able to complete an electric circuit caused by a fault in the insulation of the wire being tested.

Source: K. W. Enslow of
North American Rockwell Corp.
under contract to
Marshall Space Flight Center
(MFS-12570)

*Circle 9 on Reader's Service Card.*

## FUNCTIONAL TESTING OF VALVES AT CRYOGENIC TEMPERATURES: A CONCEPT

A concept has been generated for functionally testing valves in a dry-gas condition at cryogenic temperatures. This innovation should be particularly useful for industrial operations in which the danger of atmospheric contamination exists, such as in furnace purge lines.




Valves are normally susceptible to condensation from moisture-rich gases during functional testing at cryogenic temperatures. A concept to overcome this shortcoming is shown in the schematic. It consists of a test circuit of two solenoid-operated valves, a dry-gas source (helium), and an actuating mechanism. After the test valve is positioned, the system is purged of atmosphere by increasing the downstream pressure. This allows the bellows-or diaphragm-actuated circuit to operate, closing valve A and opening valve B to exhaust the actuating pressurant through the system. As soon as the test valve cycles and the applied gas pressure drops below the diaphragm- or bellows-set pressure (atmosphere plus a determined differential), the circuit opens and valve B closes, while valve A opens to admit dry gas (helium) to purge the system. Thus, moisture-free atmosphere can enter the system during cycling or testing of the valve.

Source: E. Goodman and M. Holben of North American Rockwell Corp. under contract to Marshall Space Flight Center (MFS-13535)

*Circle 10 on Reader's Service Card.*

## EVALUATING THERMOCOUPLE SYSTEMS

A technique has been developed for evaluating the accuracy of thermocouple systems. It is novel in that it allows evaluation of these systems with respect to a variety of parameters, such as material defects, high resistance connections, and poor workmanship. The technique, which can be used to locate and identify all abnormalities in any complete thermocouple system, may be particularly useful in chemical and pharmaceutical processing facilities in which critical temperature control is essential to production.

The normal procedure for verifying the accuracy of a thermocouple system is to check it against one or more reference-temperature points and to assume that the connections and wiring are satisfactory. In this new method, accuracy is verified by heating sequentially each wiring connection in the system, such as terminal strips or plugs, while monitoring the system output. Polarity reversals are easily determined; impurities in different lots of wire can be observed, and the type of wire, if unknown, can be determined by substituting known types. In addition, the effects of solder, lugs, and foreign metal junctions found in terminal strips or plugs may be studied and minimized as needed to obtain the desired accuracy.

Source: David A. Worcester of North American Rockwell Corp. under contract to Marshall Space Flight Center (MFS-18437)

*Circle 11 on Reader's Service Card.*

## SENSING POTENTIAL BEARING FAILURE

Previous methods for detecting potential bearing failure with cryogenic fluid testers were difficult because the thermocouples normally contacting the outer race of the bearing were slow in sensing pending problems. As a result of research, a more rapid method is now available, which may be applicable to all cryogenic bearing testers in which complex instrumentation is used.

In this method, a turbine flowmeter is installed at the exit of the bearing tester. The rate of flow at this point, when compared with a constant inlet rate of flow, gives a good indication of the heat input (from overheated bearings) to the cryogenic fluid. The heat converts some of the cryogenic fluid to gas, resulting in a rapid increase in the outlet rate of flow. This change in the outlet rate of flow (observed on the flowmeter) suggests potential bearing failure.

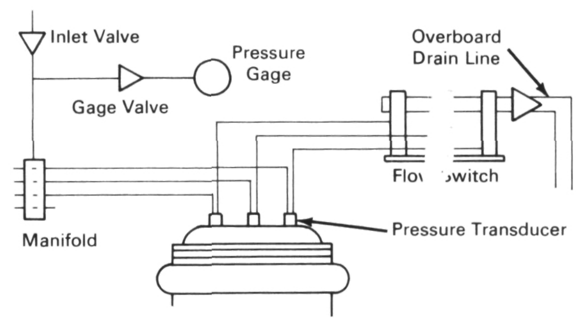
Source: Douglas A. Wagner of
North American Rockwell Corp.
under contract to
Marshall Space Flight Center
(MFS-12680)

*Circle 12 on Reader's Service Card.*

## DETECTING LEAKAGE IN PRESSURE TRANSDUCERS

A new method, in which a manifold and appropriate valves are used, has been devised to eliminate the need for testing separately a series of pressure transducers (see figure).

A pressure gage is installed in t. flow-switch panel of the stand where each transducer is plumbed to an individual flow switch. All flow switches are plumbed to an overboard drain line. Then, if the inlet valve is closed and the drain line plugged, the network can be isolated and checked for leaks by pumping gaseous nitrogen into the lines. Leakage is detected by a fall in pressure shown on the pressure gage. If leakage is observed, individual transducers are then pressurized to 125 psi for three minutes to determine the faulty one.




Source: Larry Henson of
North American Rockwell Corp.
under contract to
Marshall Space Flight Center
(MFS-90556)

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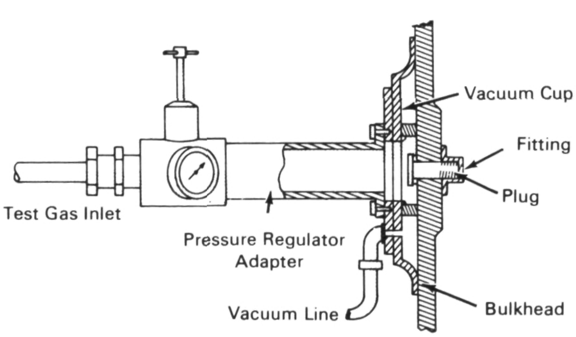
## PORTABLE FIXTURE FOR TESTING INSTRUMENTATION FITTINGS




A portable fixture has been developed that will facilitate pressure testing to detect possible leaks in instrumentation fittings mounted in the bulkhead of a large tank (see figure). It incorporates a vacuum cup that seals a pressure regulator adapter around one side of the fitting to be pressure tested, eliminating the need for a completely closed vessel.

The vacuum cup of the fixture is held against the tank bulkhead at the position of the plugged

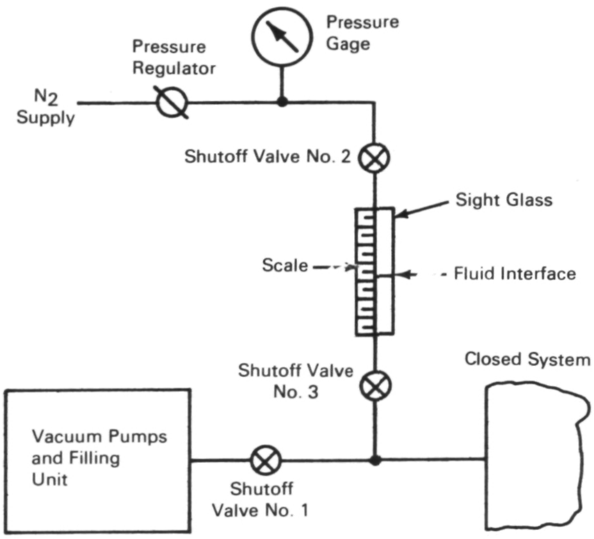
fitting, and a vacuum is drawn. Then, gas is introduced slowly through the pressure regulator adapter until the pressure reaches 15 psig. Leakage is detected with a gas sniffer at the opposite side of the bulkhead or by the bubbling of a leak-check fluid previously applied at the junction of the fitting with that side of the bulkhead.

Source: George A. Olson of
The Boeing Co.
under contract to
Marshall Space Flight Center
(MFS-02032)

*No further documentation is available.*

## TECHNIQUE FOR DETERMINING GAS IN A CLOSED FLUID SYSTEM

An improved apparatus has been designed to determine the amount of gas present in a closed fluid system by measuring the compressibility of the system's contents (see figure). When the system is completely filled with an incompressible fluid and is free of gas, its volume will not change with changes in pressure. If gas is present in the system, however, its volume will change with variation in pressure according to the gas laws. The change in volume for a given pressure change is measured with the apparatus, and from this data the volume of gas present in the system at any pressure can be determined.




Correction factors for system elasticity can be determined for any system and applied as needed. Sensitivity and accuracy of the system are proportioned to the diameter of the sight glass bore, length, and gage accuracy. Combinations or banks of sight glasses can be installed to attain greater accuracy.

Source: W. B. Wilson of
Pratt and Whitney Aircraft
under contract to
Manned Spacecraft Center
(MSC-91261)

*No further documentation is available.*

## FLAMMABILITY TESTING OF NONMETALLIC MATERIALS

A chamber has been designed for extensive flammability testing of nonmetallic materials under simulated operational conditions. This chamber allows the testing of such materials as adhesives, plastics, elastomers, and other materials in a variety of gaseous environments, from any angle or at any distance from the heat source.

The configuration of this testing equipment is completely new. The exterior structure is made of aluminum-alloy pipe with flanged ends. One end of the pipe is covered with a 1-in. circular shield of Plexiglas; the other end is covered with a circular-plate made of an aluminum alloy. During a test, materials can be moved forward, backward, upward, downward, and rotated clockwise or counterclockwise as desired. These movements are controlled by probes inserted at the point of intersection of the vertical and horizontal center lines of the main body, or inserted in the circular-plate in one of four positions. A circular repture-disk assembly is located within the chamber for pressure relief.

This chamber is preferable to presently available ones because of its capacity for vacuum or pressure testing in various gaseous environments, its greater flexibility and control, and its better economy of operation.

Source: C. L. Springfield, W. J. Paton, and J. D. Jeter
Kennedy Space Center
(KSC-10126)

*Circle 14 on Reader's Service Card.*

## SWING-TABLE SHOCK MACHINE

A swing-table shock machine has been constructed that can test large items (up to a 5-ft cube and weighing 4000 lb). The machine consists of a platform (to which the test specimen is attached) that swings in a semi-arc due to the force of gravity. The platform is guided along the semi-arc by three 12-ft arms as it is dropped from a specific height onto lead pellets on the ground (the reaction mass), producing a shock environment in excess of 100 g for 12 millisec. The shock force, shock wave, and duration of shock depend on the height of drop and the configuration of the material used to decelerate the platform.

A significant feature of this machine is the use of a swing mechanism, rather than guides or tracks, to guide the platform. This feature reduces friction, improves reliability, and lowers the cost of fabrication. The new design also allows shock testing in six directions with the aid of an L-shaped fixture.

Source: Donald J. Fessett of
North American Rockwell Corp.
under contract to
Manned Spacecraft Center
(MSC-11952)

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## TESTING FILAMENTARY COMPOSITES

The testing of filamentary composites to determine their mechanical properties has proved to be more difficult than the testing of homogeneous materials such as metals. A study has been made in which some of the aspects of the NOL ring split-dee tensile test were examined, both analytically and experimentally, to find out whether this technique could be adapted to the structural testing of filamentary composites.

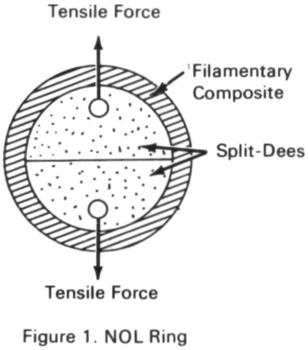



Figure 1. NOL Ring Split-Dee Tensile Test.

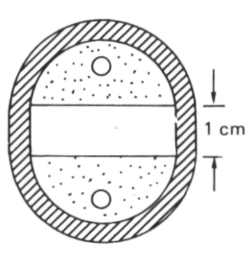



Figure 2. "Race-Track" Filament-Wound Tensile Specimen.

The NOL ring split-dee tensile test (Figure 1) has the advantages that the specimen can be readily fabricated by winding, and the test can be performed in a conventional universal testing machine without special fixtures other than the split-dees themselves. The test has two disadvantages, however: no test section is available at which strain gages can be mounted to measure the stress-strain properties, and the test introduces substantial bending moments in the ring where the split occurs between the two dees. The bending moments are of a sufficient magnitude to raise questions about the validity of the test data.

To eliminate the bending moments, a straightaway section was added adjacent to the split in the dees (Figure 2). Although a mathematical analysis of this "racetrack" specimen indicated that this does not eliminate the bending, it is substantially reduced. For example, a 1-cm straightaway reduces the bending moment to less than a half that of the circular ring. A qualitative understanding of the mechanics of the reduction of the

maximum bending moment is achieved by realizing that the midpoint of the straightaway, when loaded, deflects inward toward the center of the track. Even though the curved portions pull away from the dees, the eccentricity of the tensile load at the mid-span is small and therefore, the moment associated with it is also small.

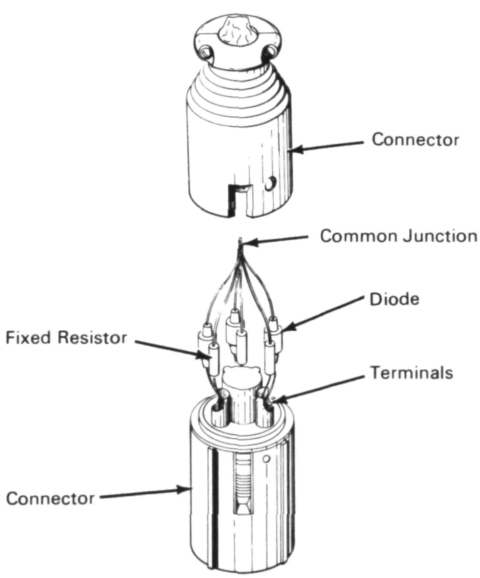
Experimental confirmation of a qualitative nature of this analysis of split-dee tests was obtained by photoelastic tests and by strain measurements on an enlarged aluminum-alloy ring.

Source: B. Walter Rosen and Norris F. Dow of General Electric Co. under contract to NASA Headquarters (HQN-10268)

*Circle 16 on Reader's Service Card.*

## ELECTRIC-LINE IDENTIFIER

This device provides a unique means for identifying individual conductors in a cable. It should be of particular interest to the communications and electric power industries.




The instrument consists of a connector with multiple terminals. A fixed diode and resistor are connected in parallel to each terminal, and the leads from the other end of the diode and resistor are connected to all the other diodes and resistors in a common junction as shown in the figure.

The value of the resistance is selected so that identifying numbers of the terminals are reflected by the value of the resistance to the terminals. For example, the number 5 terminal would have a resistance value selected that would be 5, 50, 500, or 5000 ohms. Any of these values would reflect the number 5 and identify the terminal.

The diode is installed so that current is passed in a direction toward the common junction of the resistors and diodes, and the current is blocked in the direction away from the common junction. Thus, in one direction the current bypasses the resistor and in the other direction it is forced through the resistor.

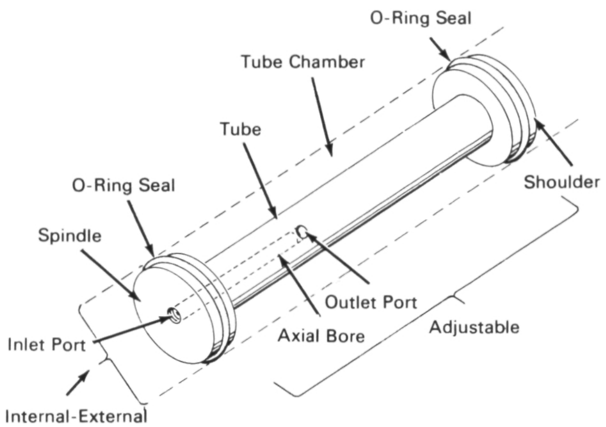
To operate this device, the portion of the connector containing the resistor and diode is plugged into the receptacle having lines to be identified, and the negative lead of an ohmmeter is connected to the line to be examined at the other end. The positive lead of the volt ohmmeter is fastened to any other line connected to any other terminal. The ohmmeter should then reflect the identifying number of the terminal to which the line is attached.

Source: Waldo E. Brown of Caltech/JPL under contract to NASA Pasadena Office (NPO-10788)

*Circle 17 on Reader's Service Card.*

## PRESSURE TESTING PIPING AND TUBING

An improved test device has been made that can introduce either pressure or vacuum into piping and tubing. The device can be inserted into an item to be tested where it secures itself in position, requiring no external support. It can operate in a range from zero to 25,000 psig and to any vacuum level that available equipment can attain.




The spindle-shaped device has an axial bore at one end, terminating in an outlet port at its center (see figure). Two shoulders, one at each end of the device, have annular grooves machined in them to retain airtight seals in the form of O-rings. The device can be inserted into the portion of tubing or piping to be tested and pressure (or vacuum) applied at the inlet port. The pressure (or vacuum) operates, by means of the axial bore and its outlet port, upon the tube chamber entrapped between the two O-ring seals.

Source: Benjamin T. Howland and Albert L. Maurin of North American Rockwell Corp. under contract to Manned Spacecraft Center (MSC-15185)

*Circle 18 on Reader's Service Card.*

## FRACTOGRAPHY FOR ANALYZING FAILURE MODES IN POLYTETRAFLUOROETHYLENE

Techniques for analyzing failures in metals are well established, and abundant data on failure modes in these materials are now available. Fractography has been a common analytical technique for studying the fracture face of a failed metal by means of both macrophotography and microphotography. As a result of a study, it was demonstrated that fractography can also be used to analyze fractured surfaces of polytetrafluoroethylene (PTFE) to determine modes of failure in this material.

In this study it was found that the fractographic principles used for analyzing failures in metals were also applicable to the analysis of the microstructure and fracture characteristics of PTFE, a material used for fabricating seals in cryogenic systems. Notched and unnotched samples of PTFE 0.25 in. thick were prepared and tested in tensile and fatigue testing machines at room temperature and at the temperature of liquid nitrogen. Replicas of the fractured surfaces were prepared by the commonly used two-stage acetate replica technique. All fractures were studied in two magnification ranges: (1) the macrorange, from 1 to 10×; and (2) the microrange, from 3500 to 15,000 × (with the electron microscope). The various topographical features on the fracture faces were defined in terms of observable patterns (chevron, dimples, tears, ridges, and striations) and tabulated for all samples.

Source: B. H. Nerren Marshall Space Flight Center (MFS-20294)

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### MEASURING LOW-ORDER HARMONIC DISTORTION

A technique has been developed to determine the total harmonic distortion of precision laboratory oscillators. A bridged-tee rejection filter is used together with a wave analyzer. The fundamental frequency is rejected by at least 120 db, and the remaining harmonic amplitudes are measured by a sensitive voltmeter. The total fundamental rejection is equal to the rejection of the bridged-tee filter plus the rejection of the wave analyzer. The fundamental rejection of the bridged-tee filter is at least 40 db, and as long as the fundamental frequency is 200 Hz or greater, the fundamental rejection of the wave analyzer is at least 80 db, leaving a total fundamental rejection of at least 120 db. As a result of this high fundamental rejection, the uncertainty in measuring harmonic distortion decreases to less than 0.001 percent.

Source: Eugene J. Gervais of
North American Rockwell Corp.
under contract to
Manned Spacecraft Center
(MSC-15577)

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# Section 2. Computer Programs and Data Reduction

### FINITE ELEMENT THERMAL STRESS ANALYSIS OF PLANE OR AXISYMMETRIC SOLIDS (FEATS)

The FEATS code was developed to solve the two-dimensional steady-state temperature distribution and the resulting thermal stress distribution in a plane or axisymmetric solid body and to obtain contour plots of the resulting distributions. The program calculates, using finite element analysis, the steady-state temperature and stress fields for either axisymmetric or plane two-dimensional bodies with boundary conditions, including specified displacements, loads, and thermal boundary conditions.

The program is a general purpose code for solving linear and bilinear stress-strain problems, thermal stress, and temperature fields. It calculates temperature distributions for materials in which the thermal conductivity is a function of temperature. The code can also calculate the axial stress in plane-strain type bodies that are free to warp.

Language: FORTRAN IV

Machine Requirements: CDC 6600 or IBM 360/75

Source: Westinghouse Astronuclear Laboratory
under contract to
Space Nuclear Propulsion Office
(NUC-10242)

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### COMPUTER UTILIZATION FOR THRUST CHAMBER TESTING

This program models the thrust chamber and test system of a vehicle. The model incorporates descriptions for heat transfer, system resistances, hydrogen properties, and combustion performance. Inputs required are the desired operating point (chamber pressure and mixture ratio), the two propellant tank pressures, the throat area (gap), and the anticipated combustion efficiency. Outputs are arranged to indicate the various system flow rates and pressures predicted as well as the parameters required to set up the test.

The GE time-share computing system is employed rather than the IBM system because the GE system can be used at remote test sites. This solution is particularly significant since

limited storage is available with the GE system which prohibits extensive table utilization.

Language: Basic

Machine Requirements: GE Time-Share Console

Source: North American Rockwell Corp. under contract to Marshall Space Flight Center (MFS-18421)

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## THERMOCOUPLE DATA REDUCTION PROGRAM

This data reduction program transforms thermocouple millivolt data to temperature. All arithmetic operations are performed in single precision. The present program was specifically written for: (1) chromel/alumel and (2) combination Platinel II - chromel/alumel thermocouple systems. The program can be easily adapted to other thermocouple systems. When submitting any job to the computer, multiple numbers of thermocouples and tests may be reduced on the same job. CRT plots of temperature as a function of time may be requested; one to six thermocouples may be plotted on a single frame.

Language: FORTRAN H

Machine Requirements: IBM 360, Release II

Source: North American Rockwell Corp. under contract to Marshall Space Flight Center (MFS-18415)

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## BLADDER FATIGUE PERFORMANCE PROGRAM

This program was developed to predict the performance of bladders used as propellant expulsion devices. A modification of an equation derived by Coffin and Manson to correlate experimental fatigue data is used. The program can be used for any metal for which yield stress and fracture ductility data are known. At present, four metals can be considered: (1) stainless steel, (2) aluminum, (3) gold, and (4) titanium iodide; for temperatures ranging from -322° to +262°F.

Accuracy of the program depends upon the accuracy of the fracture ductility data. Although the program presently computes fatigue performance only for metals, it can easily be extended to any material for which the necessary equations and data are available.

The program has two options: (1) cathode ray computer routines are used for the graphical presentation of computed fatigue data (input data consist of bladder material and a list of temperatures in °F); (2) if graphs are not desired, the input data consist of bladder material, temperature, and operating pressure difference. Program output data are the yield stress and fracture ductility, true strain, material thickness-to-fold radius, and number of cycles to failure.

Language: FORTRAN H

Machine Requirements: IBM 360, Release II

Source: North American Rockwell Corp. under contract to NASA Pasadena Office (NPO-10605)

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## BELLOWS CALCULATION PROGRAM

This program employs empirical and analytical derived-design equations on various metal bellows of different sizes in order to calculate various properties of bellows used in ducting systems. Arithmetic operations are performed in double precision. Calculations are restricted to four single bellows movements and two double bellows movements. One subroutine and one data deck are required with the main program.

The main program and the subroutine calculate bellows-spring rates, bulging, bending, and hoop stresses. Cycle life is calculated by data deck. With known bellows dimensions and type of movements supplied as data, main program and subroutine calculate spring rate, actuating force, squirming pressure, stress, bellows weight, resonant frequency, fatigue life, and convolution clearing.

Language: FORTRAN H

Machine Requirements: IBM 360, Release II
Source: North American Rockwell Corp.
under contract to
Marshall Space Flight Center
(MFS-12641)

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NASA-Langley, 1971

*"The aeronautical and space activities of the United States shall be conducted so as to contribute . . . to the expansion of human knowledge of phenomena in the atmosphere and space. The Administration shall provide for the widest practicable and appropriate dissemination of information concerning its activities and the results thereof."*

— NATIONAL AERONAUTICS AND SPACE ACT OF 1958

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